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Science is Fun- CHEMISTRY

Carbon Compounds

Start the session by asking how the students felt the previous session was (If this is not the 1st sif session) and try to break the ice by discussing about the previous sif session, what they liked the most and if they remembered all that was taught to them.

Inquisitive Question-Today, we are going to study about a very important element **Carbon**. Why do you think there is a separate chapter dedicated for carbon out of all elements? Can you give some examples of materials which contain carbon? Carbon is present everywhere in some or other form. It is present in a diamond, perfume, pencil, detergent, bench, human body, blood, proteins, amino acids, etc. Everything that you can think of contains carbon in some form or other. Let us see what the reason is behind this and how carbon can exist in so many forms.

Day to day relevance- Can you tell me two compounds of carbon that you come across in your daily life? (wait for the answer, or else proceed to question such that it leads to the answer) What is the inner core of your pencil made of? Yes, graphite, it is a form of carbon. Can you name another form of carbon, that is used in making ornaments? Diamond. Both diamond and graphite are made entirely of carbon atoms. They are called allotropes. They differ in the way the carbon atoms are attached. That makes such a huge difference though both are made entirely with carbon atoms! Diamond is known to be the hardest substance. Only a diamond can cut another diamond. It is known for its lustre. Graphite is soft and doesn't shine.

Interesting Aside: Another allotrope of carbon is fullerene. It is a spherical structure similar to a football, with hexagons and pentagons. The first one to be discovered had 60 carbon atoms (C_{60}). It was named Buckminister fullerene after the architect Richard Buckminster Fuller's geodesic dome structure, which bore a resemblance to the structure of the C_{60}. These same structures are also known as Buckyballs or fullerenes. Fullerenes are used in varioius fields including cancer therapies, superconductors, etc.

Main Script- What is an atom made up of? It is made up of protons, neutrons and electrons. We all know that protons and neutrons reside inside the nucleus whereas electrons are located in the outer shells of the atom. What is atomic number of an element? It is given by the number of protons or number of electrons. Number of protons is equal to number of electrons. The electrons in an atom are distributed over the electronic shells by the formula $2n^2$ where 'n' represents the shell number. The naming of the shells starts from the letter 'K'. Let us consider the first four shells K, L, M, N. The number of electrons arranged in each shell follows the rule $2n^2$ and it goes as follows:

Suggested Activity : Students are asked to calculate on the board

As this is a relatively simple formula for the tenth standard students, one member from the class is asked to come up to the board for them to calculate for each case where n=1,2,3,4 .

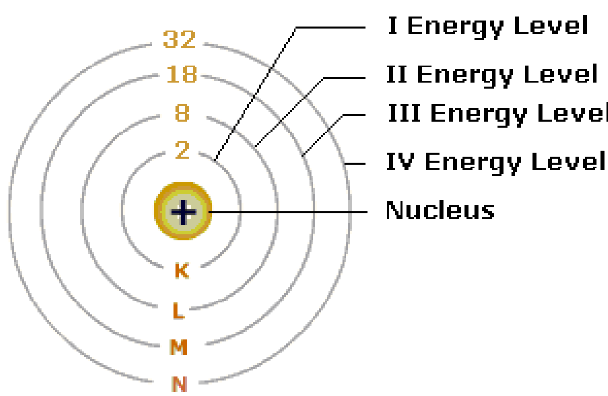
K-shell no 1: n=1; $2\ (1)^2 = 2$, which means the ‘K’ shell can accommodate 2 electrons.

L-shell no 2: n=2; $2(2)^2 = 8$, ‘L’ shell can accommodate 8 electrons.

M-shell no 3: n=3; $2(3)^2 = 18$, ‘M’ shell can accommodate 18 electrons.

N-shell no 4: n=4, $2(4)^2 = 32$, ‘N’ shell can accommodate 32 electrons.

Thus the electronic configuration of K,L,M,N shells is 2,8,16,32.



For any atom to attain stability, the shell has to be completely full or empty or have 8 electrons in the outermost shell

Now, let us see some examples.

Main Script: What is the atomic number of Sodium? It is 11. The electronic configuration of Sodium is 2, 8, 1. Sodium can easily lose an electron to gain stability than gain 7 electrons. Let us take another example, oxygen. The atomic number of oxygen is 8 and hence its electronic configuration is 2,6. Oxygen can easily accept two electrons from some other element so that its 2nd shell becomes full and it can gain stability.

If we now look at both Na and O, we can see that Na is ready to give away one electron and oxygen is ready to accept two electrons. By bringing two atoms of Na and one atom of oxygen together, we can make this possible.

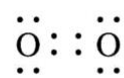
This is called as ionic bond, where one atom gives away and the other atom accepts. This forms a very strong bond between the two atoms.

Value content: What can we learn from ionic bonding? When we extend help to our friends by giving away what they need, just like how the sodium atom gives away its electron to oxygen, we build strong relationships. Our friendship becomes very strong. We will gain a lot of happiness by giving away, which is a benefit to us and even they will benefit by receiving what they need.

Main Script: Now, what if both the atoms want to gain or give? In the previous case, one atom wanted to give and one wanted to receive. What if both want to either gain electrons or give away electrons at the same time? They share electrons. Let us assume that there are two boys, A and B sitting on a bench. A has an eraser and no sharpener and B has a sharpener and no eraser. Both A and B require both eraser as well as a sharpener. What will they do? Will A give away his eraser to B because B needs it? No. He cannot. A also needs the eraser. Will B give away the sharpener just because A needs it? No. Best way to have both eraser and sharpener is to share them. If A can place his eraser in the center of the bench and B can place his sharpener similarly in the center, both can share both. Similarly, when two atoms want to give or gain electrons at the same time, they share electrons.

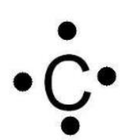
Let us take the example of Oxygen molecule, O_2. It consists of two oxygen atoms. Both the oxygen atoms have six electrons in the outermost shell and both require 2 more electrons to gain stability.

In this case each oxygen atom shares two of its electrons with the other oxygen atom.

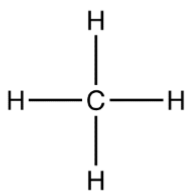


This is called as covalent bonding. When two atoms share their electrons to become stable, they form covalent bonds.

Now, let us look into carbon. The atomic number of carbon is 6. Its electronic configuration is 2, 4. It has 4 electrons in its outer most shell. To gain stability, it has to either lose all four electrons or gain four more electrons. If it loses all four electrons, then there will be six protons holding only two electrons, which is highly unstable. Again, if it gains four electrons, six protons will be holding on to 10 electrons, which is not possible. So it follows the concept of sharing electrons. The four valence electrons of carbon act as four hands. It can combine with any atom that requires an electron and is ready to share with carbon.



These are some of the examples of carbon combining with hydrogen atoms. A compound of hydrogen and carbon is called as hydrocarbon.



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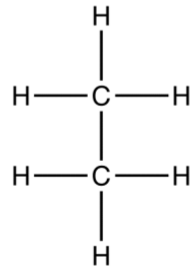

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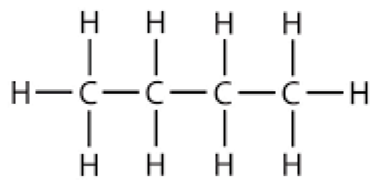
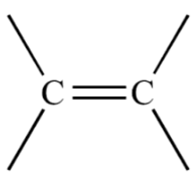


The carbon chains can keep extending. The ability of carbon atoms to combine with themselves to form long chains is called as catenation.

Interesting Aside: Carbon can form chains with other carbon atoms having more than 1 lakh atoms whereas other elements cannot form to this extent. This is due to the optimum size of carbon atom, bond strength and its valency, i.e. in this case the ability of one carbon to bond with four other carbons. This is the reason why carbon is present everywhere. It can combine with itself to form more and more complex compounds.

Main Script: It can also form double and triple bonds with other carbon atoms



It becomes unstable when it tries to form four bonds with another carbon atom

Now, let us see how carbon compounds are named. Just as we have three names, first name, middle name and last name, carbon compounds have FN, MN, LN.

Let us take an example of a carbon compound, ethanol. What is the chemical formula of ethanol? It is C_2H_5OH. Let us split ethanol into its FN, MN and LN.

ETH	AN	OL
↓	↓	↓
No of Carbon atoms	No of bonds between 2 C atoms	Functional group

1 → Meth	1 → AN	OH → ol (Alcohol)
2 → Eth	2 → EN	COOH → oic acid(carboxyl)
3 → Prop	3 → YN	CHO → al (aldehyde)

Thus the 1st name represents the number of carbon atoms, middle name comes from the number of bonds between two carbon atoms and the last name from the functional group of the carbon compound.

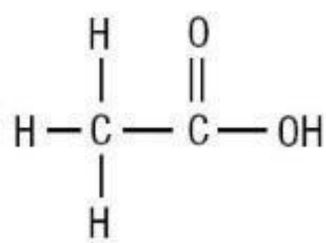
Suggested Activity: SHOUTING THE NAMES OF THE COMPOUND

The volunteer plays a game with the students where he randomly points to at one of the three parts of the name and the students are made to shout as a class the various permutations and combinations

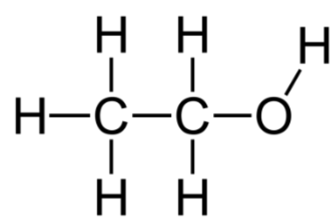
Vis a vis the volunteer can ask the class to arrive a name with the structure

Make the students arrive at the structure of ethanol and ethanoic acid using the concept of FN, MN, LN. Following are the structures:

Ethanoic acid



Ethanol



Today, we are going to perform some activities using ethanol and understand the properties of carbon compounds.

All carbon containing compounds are called Organic compounds. The study of organic compounds is called Organic Chemistry. Because of the chemical properties of carbon atom, many of the carbon containing compounds are the most widely used fuels. Eg: Petrol, Diesel (mixture of hydrocarbons), Wood, Plastic, Ethanol, methanol etc. In the presence of Oxygen, these compounds can get oxidized easily and hence many of these easily catch fire.

Suggested Activity 1:

Each table has three beakers, numbered 1, 2, 3 - one containing only water, second only ethanol and the third one containing a mixture of water and ethanol in the ratio of 1:3. There will be an A-4 sheet at each table. Ask the students to divide the sheet into three parts. Once this is done, ask one student from each group to dip one piece of paper into the beaker containing only water, i.e. beaker number one, with the help of a pair of tongs. Once the paper gets soaked *completely, ask them to take it out and light the paper in a candle flame by keeping it for 3 seconds. They will observe that the paper doesn't burn. Now, ask them to do the same with the 2nd piece of paper, this time, dipping into the 2nd beaker containing only ethanol. The piece of paper will catch fire immediately and burn to ashes. Let them repeat the process with the 3rd piece of paper and the third beaker containing a mixture of water and ethanol. This time, they will observe that the paper seems to burn, but it doesn't actually burn to ashes. Once the fire gets extinguished, the paper can be seen in the same form as it was before.*

Explanation: The 1st beaker contains water. Boiling point of water is 100°C. That means, when the temperature of water reaches 100° C, it turns into steam. The paper is covered with a layer of water which will evaporate only at 100°C. The heat supplied through the flame is not sufficient for the water to get evaporated. (If the paper is kept in the flame for a longer time such that all the water evaporates, then the paper will catch fire. But here our time frame is a few seconds). Hence, it protects the paper from getting burnt. In the 2nd case, the beaker contains ethanol. It is a highly flammable fuel and its boiling point is low, 76° C. The heat supplied is sufficient for ethanol to catch fire in a few seconds. Hence the paper burns immediately. The 3rd beaker contains a mixture of water and ethanol. When heat is applied, the ethanol catches fire immediately as its boiling point is very low. Hence the paper appears to burn. But it doesn't actually burn because it is still protected by the layer of water which doesn't catch fire.

Suggested Activity: The volunteer has to stress on safety of this experiment. The students should listen to instructions and not be playful especially during this experiment as it is highly exothermic.

(Make sure that the room is dimly lit for this particular activity to achieve best results) There will be a test tube containing sulfuric acid at each table. Each group will have a beaker containing ethanol. Ask them to pour the ethanol along the walls of the test tube keeping the test tube in a slanting position so that ethanol doesn't mix with the acid. Once it is poured, the students will be able to see a layer separating sulphuric acid and ethanol. Ask the students to place the test tube in the conical flask. Now, ask them to take potassium permanganate powder from the table and introduce into the test tube with a spatula and move away from the table. As soon as the potassium permanganate reaches the interface separating acid and ethanol, there will be lightning seen inside the test tube.

Explanation: Ethanol is a fuel. It burns in the presence of oxygen. Potassium permanganate and sulfuric acid react to produce some ozone, which has a high oxidizing power and rapidly oxidizes the alcohol, causing it to combust.

(For their understanding, explain that ozone is stronger oxidizing agent w.r.t. oxygen. In the previous activity, ethanol burnt in the presence of oxygen. So, a more explosive reaction would be expected here. Ask them if they have heard about ozone previously. Most of the students would know about ozone from 'ozone depletion' and 'global warming'). The formula of ozone is

O_3. Ethanol gets oxidized to ethanoic acid in this process. This is a very violent reaction which produces heat. The layer of ethanol prevents oxygen and heat from escaping due to which we can see the thunderstorm at the interface.

Extra info for volunteer, just in case students ask- An approximate equation for the ozone formation is shown below.

$6\ KMnO_4\ (aq) + 9\ H_2SO_4\ (aq) \rightarrow 6\ MnSO_4(aq) + 3\ K_2SO_4(aq) + 9\ H_2O(l) + 5\ O_3(g)$

TROUBLESHOOT: Sometimes sulfuric acid may be dilute. In such cases, add more $KMnO_4$ for the reaction to take place.

Safety: It is suggested that students move away from their tables to the demo table once the activity is over, as the sparks continue in the test tube for a long time

Suggested Activity:

MICELLES: It is better to be explained here and not in the theory. Depth of explanation depends on the way it is explained in the text book

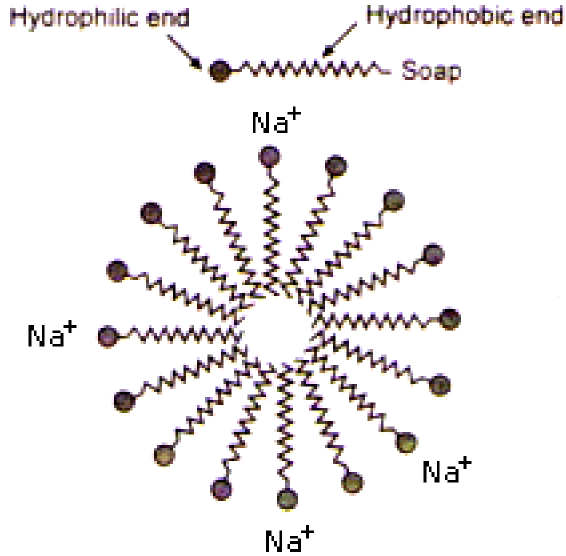
This is a demonstration only. At each step, students may be asked to come forward and do it. Take a flat bowl and pour about 250mL of milk. Add one drop of each of the four colors of food coloring—red, yellow, green, and blue—to the milk. Keep the drops close together in the center of the bowl of milk. Now dip a cotton swab into a liquid dish soap (preferably Pril/Vim). Place it in the middle of the milk and hold it there for 10 to 15 seconds. A burst of colors can be seen. The colors will start to spread away from the soap drop and mix and churn.

NOTE- Solid food color can be used by dissolving them in ethanol/water

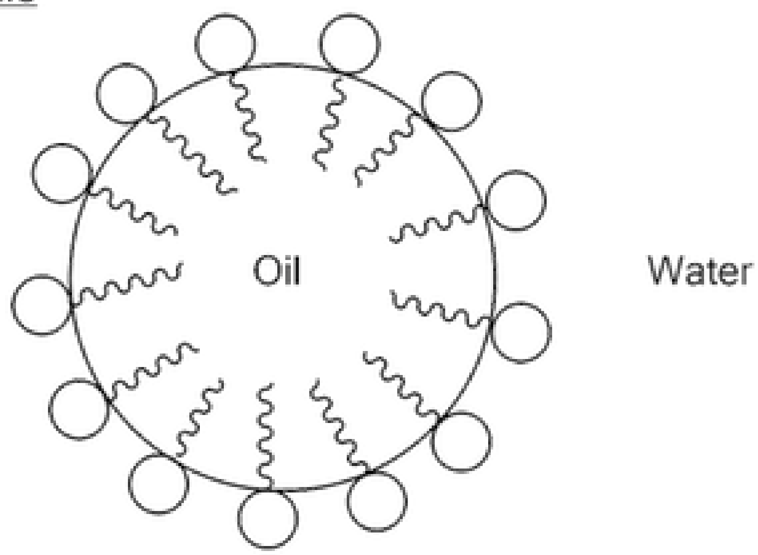
Explanation: Inquisitive Question: Have you anytime dropped food on your dress while eating? (yes) What did you do to remove the stain? (Washed with soap). Why do you think the soap could clean the stain and not plain water? How does the stain go by washing with soap? Ans: We know that water and oil are immiscible, i.e. they don't mix. The food contained oil and so couldn't be washed with plain water. So to remove the oil, what should be used? (Wait for the answer. Expected answer- soap) Yes, we need to add something that can dissolve the oil. But how does the soap do it?

Main Script: Those substances that dissolve in water are hydrophilic (hydro=water; phyllic=loving), and those that can't are hydrophobic (hydro=water; phobic= hating). Oil is an example of hydrophobic substance as it doesn't mix with water as two distinct layers can be seen. Oil and water are like two enemies who don't mix with each other. Soap helps them mix together. Can anyone explain the reason?

Soap molecules form structures called micelles. It has a 'head' which is the Na^+ or K^+, and a 'tail' which is a long chain of carbon atoms (ending with the carboxylic acid functional group, as in, -COO^-Na^+). The following diagrams represents it.



Micelle



The carbon chain dissolves in oil (hydrophobic) and the ionic end dissolves in water (hydrophilic). When the cloth is shaken in water, the oil and dirt is removed from the cloth and gets into the water, rendering the cloth clean.

On a similar note, milk contains fats (oily droplets seen in the milk) which are hydrophobic and water molecules which are hydrophilic. When you put a drop of the detergent, the hydrophobic parts of the micelles attach to the fats and hydrophilic parts dissolve in water. The hydrophobic part tries to separate out the fats from the liquid as a result of which you can see the colors being spread across the milk. The colors only help us to see the movement of fat molecules in the milk.

Activity:

Give an empty dry pet bottle to every group. Ask the students to make a small hole (of 5mm dia) at the bottom of the bottle using a heated nail. Cover the hole with the finger and add *about 10mL of ethanol in the bottle. Close the cap and shake the bottle thoroughly for about 10 seconds. Then, remove the cap and empty the bottle. Ensure that there is no ethanol left in the bottle. Replace the cap. Make sure that the hole is covered at the bottom all through the process. Now, place the bottle on a ramp, uncover the hole at the bottom and place a lit candle at the hole. The bottle will fly around making a high pitched sound.*

Explanation: Once the bottle is drained, what is left inside the bottle is ethanol fumes. When the match stick is brought near the hole, the ethanol fumes burn in the presence of oxygen to release carbon dioxide and water

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

The carbon dioxide fumes gush out of the small hole at the bottom due to which the bottle propels forward at a great speed and water is left behind in the bottle.

Day to day relevance: Ethanol is not used as a fuel in vehicles because it does not produce as much energy as petrol and diesel and is very costly.

NOTE TO THE VOLUNTEER: It is advisable to get as many answers as possible from the children by way of questioning. Also, students should be encouraged to answer, even if they are wrong answers. They should be appreciated for giving it a try. A note of appreciation to those who answer correctly would go a great way in boosting their confidence.

Revise from the beginning.